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ORIGINAL ARTICLE

Cervical spondylotic myelopathy: the prediction of outcome following surgical intervention in 93 patients using T1- and T2-weighted MRI scans

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Abstract

Introduction Cervical spondylotic myelopathy (CSM) can lead to significant disability through a spectrum of clinical manifestations ranging from dexterity loss to more profound weakness, incontinence and paralysis.

Aim To determine the outcome of surgical decompression for CSM and investigate pre-operative predictors of outcome.

Methods Prospectively collected data on all patients who underwent decompressive surgery for CSM and completed 12-month follow-up were reviewed. Data on age, MRI T1 and T2 signal changes pre-operatively, surgical approach and the Nurick's Myelopathy Grade (NMG) was analysed pre-operatively and 1 year post-surgery.

Results Data on 93 consecutive patients who underwent surgery for CSM were reviewed. Median age was 62 (23–94) years and 59 % were male. The median follow-up was 37 (17–88) months. The approach was anterior in 38 (42 %) patients, posterior in 55 (58 %); improvement was not significantly different when the two groups were compared. The number of levels decompressed increased with age (*p* value <0.0001). The group with a pre-operatively high signal on T1-weighted MRI images [$n = 28$ (30 %)] was associated with less neurological recovery post-operatively compared to the patients with a normal T1 cord signal. None of the patients deteriorated neurologically post-operatively, while 66 % improved by at least one NMG.

Conclusion Surgical decompressions for CSM stop the progress of symptoms at 12 months post-surgery and may result in a significant improvement of NMG in two-thirds of the patients. Changes in the T1-weighted MRI images predict worse outcomes following surgery.

Keywords Cervical spondylotic myelopathy · Decompression · Outcome · MRI

Introduction

The exact prevalence of cervical spondylotic myelopathy (CSM) is not known but is considered to be a leading cause of spinal cord dysfunction in the adult population [1]. The natural history of the condition appears to favour progression in the majority of cases [2] with up to 60 % of patients deteriorating clinically without surgical intervention. The likelihood of improvement with conservative management was small [3–6] with some studies showing progressive deterioration in all patients without surgery [7]. Surgery appears to be an effective management option not only in stopping the symptom progression but serves as a catalyst for functional improvement in this group of patients [8, 9]. In this paper, we aim to explore outcome predictors in a consecutive cohort of patients managed surgically for CSM and investigate the surgical outcome comparing the anterior and posterior approaches.

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Methods

Prospectively collected data on all patients surgically treated for cervical spondylotic myelopathy (CSM) in one spine surgical unit were reviewed. CSM diagnosis was based on clinical examination and confirmed by MRI scans. Patients with the primary diagnosis of CSM who were surgically managed over the period of 4 years between June 2006 and June 2010 with a minimum follow-up of 12 months were included. Data on age, gender, pre-operative MRI cord signal changes in T1- and T2-weighted images, operative data such as the surgical approach (anterior or posterior), the number of levels decompressed, type of surgical intervention (anterior cervical decompression and fusion (ACDF), corpectomy, cervical disc replacement (CDR), posterior decompression ± fusion, laminoplasty) were documented. Nurick's classification system for myelopathy (NMG) [10] was used to grade the gait abnormality in patients pre-operatively and 1 year post-operatively (Table 1). Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS v.17); following normality studies, the data are presented as median (range). Significance was tested with non-parametric tests for continuous data, while Chi-square test was used for categorical data. A binary logistic regression analysis model was used to explore the predictors of improvement in NMG post-surgery.

Results

93 consecutive patients who underwent intervention were prospectively enroled in the study over a period of 4 years. The median age of the patients was 62 (23–94) years of which 59 % were male. The median follow-up period was 37 (17–88) months. An anterior approach was used in 38 (42 %) patients, while a posterior approach was used in the remaining 55 (58 %) patients. In the anterior approach group, 28 patients were treated with ACDF, 6 had corpectomy and 4 had CDR. In the posterior approach group,

Table 1 Summary of the Nurick's Myelopathy Grading (NMG)

Grade 0	Signs or symptoms of root involvement but without evidence of spinal cord disease
Grade 1	Signs of spinal cord disease but no difficulty in walking
Grade 2	Slight difficulty in walking which does not prevent full-time employment
Grade 3	Difficulty in walking which prevents full-time employment or the ability to do all housework, but which was not so severe as to require someone else's help to walk
Grade 4	Able to walk only with someone else's help or with the aid of a frame
Grade 5	Chair-bound or bedridden

45 patients had posterior decompression (laminectomy) and fusion, while 10 were treated with laminoplasty.

The number of levels decompressed increased with age (Pearson correlation coefficient = 0.41, p value < 0.0001), 15 patients with a mean age of 52 years had one level decompressed, 12 patients with mean age of 64 years had two levels decompressed, 14 patients with a mean age of 68 years had three levels decompressed, 13 patients with a mean age of 68 years had four levels decompressed and 15 patients with a mean age of 70 years had five levels decompressed.

Younger patients were managed with CDR (n 4) with a mean age of 37, laminoplasty (n 10) with a mean age of 51, and ACDF (n 11) with mean age of 54 while older patients underwent corpectomy (n 6) mean age of 65 and posterior decompression and fusion (n 45) with a mean age of 73 years. Posterior instrumented fusion was performed on all patients who underwent posterior laminectomy.

Anterior vs. posterior approach

Selection of approach was based on age, number of levels involved and cervical spine alignment (kyphotic or lordotic) [11]. When compared to the anterior approach, patients within the posterior approach group were significantly older, had a worse pre-operative gait (as indicated by their NMG), had a higher prevalence of T2-weighted cord signal changes on MRI and demonstrated more modest improvement post-operatively. With this in mind, both groups demonstrated a significant post-operative improvement in their NMG (p value <0.0001 for both groups, Wilcoxon signed-ranks test). Table 2 outlines the variances between the two surgical groups (anterior vs. posterior approach).

Cord signal changes and post-operative improvement

When cord signal changes on the T2-weighted images were considered, there was no significant difference in NMG improvement post-surgery when patients with a positive signal change [n = 65 (70 %)] were compared to patients with a normal cord signal [n = 28 (30 %)] in this imaging sequence (p value 0.96, Chi-square test). On the other hand, a significantly lower improvement in the NMG was noted in patients with a positive cord signal change in T1-weighted images [n = 28 (30 %)] compared to those with a normal cord signal [n = 63 (70 %)] in this phase [NMG improvement = 0 (1), 1 (1), respectively, p value 0.028, Chi-square test]. Pre-operative better NMG scores were recorded amongst patients with normal cord signal on T1- and T2-weighted MRI images (Fig. 1), while worst post-operative improvement was identified amongst patients with pre-operative cord signal changes in both T1- and T2-weighted images (Table 3).

Table 2 Comparison between the patients who underwent an anterior approach to those who were managed through a posterior approach

	Anterior approach	Posterior approach	p value
N	38	55	
Mean age	51 (17)	73 (19)	<0.0001
Male gender	59 %	59 %	NS
Number of levels [median (IQR)]	1 (1)	3 (1)	<0.0001
Number of levels (range)	1–4	1–5	
Positive MRI T2 signal changes	62 %	76 %	0.17
Positive MRI T1 signal changes	18 %	38 %	0.03
NMG pre-operative [median (IQR)]	2 (2)	3 (2)	0.015
NMG post-operative [median (IQR)]	0.5 (2)	2 (3)	0.002
Improvement in NMG	1 (2)	1 (1)	0.055

IQR interquartile range

Predictors of post-operative NMG improvement

None of the patients showed any deterioration in gait following surgery. At the time of final assessment, 34 % of the patients did not show any improvement in the post-operative NMG score. Of the remaining group (66 %) who improved, 46 % improved by one NMG grade, 16 % improved by two NMG grades while 4 % achieved an improvement of three grades. Figure 2 illustrates that an improvement was achieved even amongst the higher NMG grades.

A binary logistic regression model investigating improvement by 1 or more NMG grades against age, gender, surgical approach, type of surgical intervention, extent of decompression (number of levels decompressed), pre-operative NMG and pre-operative cord signal changes on MRI (for both T1- and T2-weighted images) did not identify significant improvement predictors (Table 4).

Complications

We have not identified any complications related to implants; However, we encountered five complications in five patients; three superficial wound infections all in patients who were managed through a posterior approach, one wound dehiscence in a case managed with laminoplasty and one fatality due to catastrophic post-operative upper gastrointestinal bleeding.

Discussion

Irrespective of the surgical approach, the main objective of surgery in CSM is to achieve adequate spinal canal decompression while maintaining or restoring spinal stability. This ultimately results in improved cord perfusion and reduced cord oedema [12]. In our cohort, posterior decompression surgery was largely performed in older
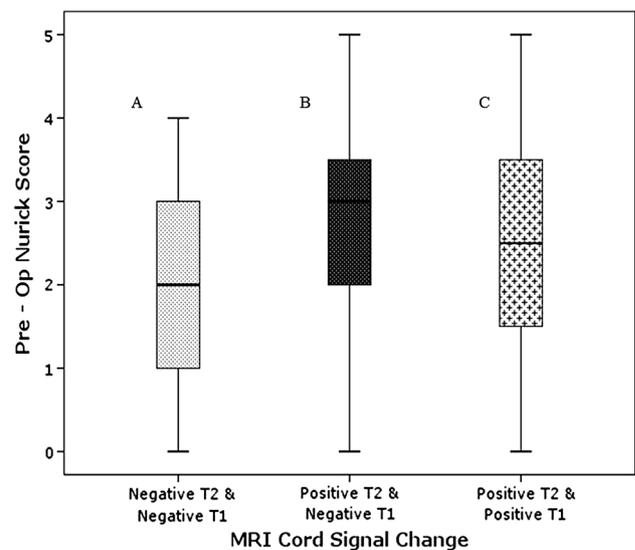

Fig. 1 Median pre-operative NMG scores for the three groups. The scores of *a* group were significantly better than group *b*, *p* value = 0.004, Mann–Whitney *U* test and better than group *c* although statistically not significant (*p* value = 0.37, Mann–Whitney *U* test). There was no significant difference between groups *b* and *c* (*p* value = 0.5, Mann–Whitney *U* test)

patients who had multilevel compression and significantly worse NMG scores. This selection bias, we believe, resulted in a smaller post-operative NMG improvement compared to the anterior surgery group making our findings at odds with previously published evidence that suggested no significant difference in the post-operative functional outcome between the two groups [13–17]. A recent systematic review suggested a similar outcome between the two approaches based on eight level III retrospective cohort studies; the authors concluded that there was no significant difference when the improvements in JOA (Japanese Orthopaedic Association) scores and post-operative C5 palsy rates (0–10.2 %) were compared, but the infection rates were lower with anterior surgery and dysphagia

Table 3 Breakup of the patients in relation to the cord signal change on MRI (n), median improvement in NMG post-surgery

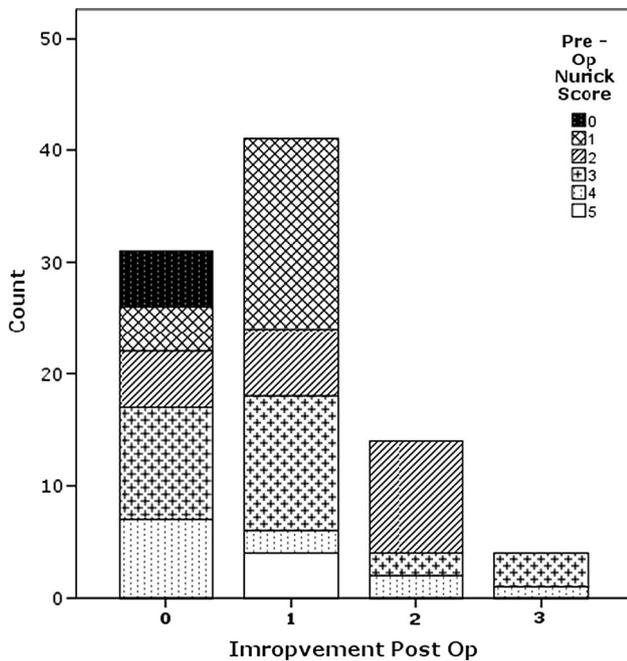|	Abnormal signal on T2-weighted images	
	Present	Absent
Abnormal signal on T1-weighted images		
Present	n = 28, 0 (1), p value 0.002*	n = 0
Absent	n = 37, 1 (2), p value <0.0001*	n = 23, 1 (1), p value < 0.0001*

* Chi-square test

Fig. 2 The post-operative improvement in NMG

Table 4 Binary logistic regression analysis investigating predictors of improvement by one or more NMG grades post-surgery for CSM

Factor	OR (95 % CI for OR)	p value
Gender	0.37 (0.13–1.07)	0.067
Age	1.00 (0.95–1.05)	0.905
Type of surgical intervention	1.29 (0.09–17.6)	0.83
Number of levels	1.30 (0.77–2.2)	0.33
Pre-operative NMG	0.73 (0.47–1.13)	0.16
Cord signal change on MRI		
T1-weighted sequence	2.88 (0.92–8.95)	0.068
T2-weighted sequence	1.13 (0.29–4.32)	0.86

OR odds ratio, *CI* confidence interval

rate (7.1–30 % in anterior compared to 0 % for posterior) was lower with posterior surgery [18].

We considered additional factors when choosing the approach including the location of the compressive abnormality and the sagittal alignment of the cervical spine pre-operatively. With posterior decompression, a peak post-operative spinal cord shift >3 mm was associated with a good clinical outcome and was mostly observed in the lordotic compared to straight or kyphotic cervical spine (3.1,<3, <2 mm, respectively) [11].

A posterior decompression was therefore considered contraindicated in patients with a neutral or a kyphotic cervical spine [12] but the findings at follow-up for an average of 5.6 years of 136 patients (mixed cohort of disc herniation and spondylosis) comparing the two approaches identified no significant difference in the neurological recovery as long as the normal anatomic sagittal alignment of the cervical spine is maintained or restored with posterior surgery [19]. Furthermore, Chiba et al. reviewed 70 patients who underwent posterior decompression for CSM with post-operative cervical malalignment and hypothesised that the "slack in the cord" due to the spinal loss of height with degeneration allowed for an acceptable recovery even in a kyphotic or straight spine [20].

Cord signal changes

Although an MRI signal change is not uniformly present in all patients with CSM, signal changes in T1- and in T2-weighted sequences were suggested to indicate a worse clinical picture and predicted limited neurologic improvement after decompression surgery [21–25]. Three patterns of MRI cord signal change in T1/T2 sequences were described in CSM; normal/normal, normal/high and low/high [22]. Such changes were suggested to reflect various stages of intra-spinal oedema, neuronal death, gliosis, microcavitation, and/or demyelination [12] and described to indicate chronicity and severity of the compression [24]. When the patterns were compared in a number of studies, the neurologic recovery was better in patients who had normal cord signal in the T1-weighted sequence [21, 22] as was multi-segmental high-intensity changes on T2-weighted sequences [23] and well-defined signal change borders on T2-weighted sequences [26]. In our cohort, the absence of cord signal change was associated with a better NMG score, but significant neurological improvement was recorded in patients irrespective of the cord signal change pattern. The maximum improvement was identified in patients with a normal/high signal, which might be explained by the severe pre-operative NMG in a cord that

has not lost the capacity to recover (cord oedema but no fatty infiltration/irreversible grey matter necrosis [27]). The least improvement was observed in those with a low/high cord signal pattern.

Predictors of outcome

It is recognised that the patient's over all condition such as an associated neurogenic or vascular claudication, hip/knee advanced osteoarthritis and cardiopulmonary reserve adversely affect the NMG [10]. We have not adjusted our analysis for such factors but we found age not to have a significant predictive effect on post-operative improvement in our cohort. Kawaguchi et al. also found the post-operative improvement amongst 20 patients older than 70 years of age not to be significantly different from 69 younger patients [28].

The time from onset of symptoms is a very elusive parameter. What might be recalled by one patient as abnormal might escape another as relevant. A reasonable proportion of CSM are elderly and suffer with degenerative changes in their upper and lower limbs which might affect their walking, writing and even interfere with fine movements in the hands. Authors who considered this factor in their analysis suggested that earlier intervention results in a better prognosis [29–31]. Other factors implicated for poor post-operative outcome include pre-operative bladder dysfunction [29] and post-operative kyphosis [32]. Our experience with posterior decompression has been to add a postero-lateral instrumented fusion in the area of decompression with the aim to restore pre-operative cervical anatomic alignment and prevent the post-operative destabilising effect of an isolated laminectomy. This has been implicated in iatrogenic kyphosis post-laminectomy and was shown not to be influenced by the number of decompressed levels, resulting in a recurrence of the myelopathic symptoms through progression of compression at adjacent levels [33, 34]. We were unable to identify factors predictive of post-operative outcome in this study; the cord signal changes in the T1-weighted images did not reach statistical significance but had a reasonably good odds ratio for predicting a one or more NMG improvement post-operatively [OR = 1.13 (0.29–4.32)].

We appreciate there was a selection bias in the study because of age difference but we were unable to address that as the type of surgery was related to the age and number of levels affected.

Our study demonstrates that a favourable outcome is expected with the majority of patients managed with surgical decompression for CSM regardless of the approach or the type of surgical intervention. An adequate decompression is expected to halt the progression of the condition and improve function in a good proportion of the patients irrespective of the pre-operative severity of symptoms or MRI scan changes although a T1 signal change might suggest a more reserved post-operative outcome.

Conflict of interest None.

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